The Center for Auto Safety
Your Independent Voice for Auto Safety, Quality, & Fuel Economy
1825 Connecticut Ave. NW Suite 330 Washington DC 20009
www.autosafety.org

December 9, 2019

James C. Owens, Acting Administrator
National Highway Traffic Safety Administration
M-30, U.S. Department of Transportation
1200 New Jersey Avenue SE
West Building, Ground Floor, Room W12-140
Washington, DC 20590

Submitted electronically via www.regulations.gov

RE: Advance Notice of Proposed Rulemaking; Federal Motor Vehicle Safety Standard No. 111, Rear Visibility; Docket Number NHTSA-2018-0021

Dear Acting Administrator Owens:

The Center for Auto Safety (Center) appreciates the opportunity to comment on the agency's Advance Notice of Proposed Rulemaking (ANPRM) regarding camera-based rear visibility systems (CMS). The Center, founded in 1970, is an independent, non-profit, member-driven consumer advocacy organization dedicated to improving vehicle safety and quality for our members and all drivers, passengers, and pedestrians across the country. On behalf of our members nationwide, the Center urges the National Highway Traffic Safety Administration (NHTSA) to not amend Federal Motor Vehicle Safety Standard (FMVSS) No. 111 until research and data establish with reasonable certainty that CMS provide at least the same level of safety as do conventional mirrors.

Over the last five decades, the Center has focused on advancing safety technology for consumers from airbags to anti-lock braking, from electronic stability control to automatic emergency braking. We have long supported innovative technology proven capable of reducing deaths, injuries, and crashes, on the nation's roads. Although CMS may hold promise, research and data have yet to substantiate their safety capabilities as a standalone alternative compliance option in lieu of rearview mirrors under FMVSS No. 111. As NHTSA is aware, even auto industry representatives such as Tesla and Daimler seeking this change exclusively cited improved fuel economy, not safety, as the primary benefit of CMS. As NHTSA has noted, those petitioning for this change provided "no objective data or analysis to aid the agency in determining the net effect on safety of amending FMVSS No. 111."[1] FMVSS No. 111 was written with the understanding of how human vision and mirrors interact. The interaction between human vision and CMS

[1] Advance Notice of Proposed Rulemaking, Federal Motor Vehicle Safety Standard No. 111, Rear Visibility, 84 Fed. Reg. 54,533, 54,535-36 (Oct. 10, 2019).

screens is fundamentally different in many crucial aspects. Furthermore, permitting CMS as an alternative compliance option could preempt state safety laws, introduce new procedures unfamiliar to state vehicle inspectors, and pose challenges for law enforcement ensuring that rear visibility devices remain operational.

A. FMVSS No. 111 was Written with Mirrors in Mind.

FMVSS No. 111's field of view (FoV) requirements[2] encompass more than what they literally require. They do not literally require that a compliant mirror offer binocular depth perception and parallax from head/body motion, because mirrors already do. They do not literally require that the image resolution be above certain quality across the entire field of regard (FoR) enabled by head/body motion, because mirrors already produce images essentially as detailed as human vision is capable of perceiving. They do not literally require that images be transmitted to the driver with minimal latency, because mirrors already reflect images in real time.

The FoV requirements were written with unit magnification mirrors in mind. Unit magnification mirrors have "a reflective surface through which the angular height and width of the image of an object is equal to the angular height and width of the object when viewed directly at the same distance except for flaws that do not exceed normal manufacturing tolerances."[3] Prior to the 1982 amendment to FMVSS No. 111, only unit magnification mirrors could be used to meet the FoV requirements.[4] The 1982 amendment permitted using convex mirrors on the passenger side to meet the FoV requirements; however, to address convex mirrors' distortion of image sizes and that of depth perception, NHTSA had to set a maximum-radius-of-curvature requirement and require that the convex mirrors be permanently marked with the warning "Objects in Mirror Are Closer Than They Appear."[5] Since even an FMVSS amendment as simple as permitting mirrors of a different kind entailed additional requirements to accommodate the properties of convex mirrors, permitting CMS would call for a major overhaul of FMVSS No. 111. CMS and mirrors produce images in fundamentally different ways. Whereas mirrors provide 3-dimensional spatial information to drivers and allow drivers to change the FoV through head movements, CMS displays are static when viewed from different angles.[6]

---

[2] Standard No. 111; Rear visibility, 49 C.F.R. § 571.111 S5.2.1, S5.3 ("Each passenger car shall have an outside mirror of unit magnification. The mirror shall provide the driver a view of a level road surface extending to the horizon from a line, perpendicular to a longitudinal plane tangent to the driver's side of the vehicle at the widest point, extending 2.4 m out from the tangent plane 10.7 m behind the driver's eyes, with the seat in the rearmost position. The line of sight may be partially obscured by rear body or fender contours. The location of the driver's eye reference points shall be those established in Motor Vehicle Safety Standard No. 104 (§ 571.104) or a nominal location appropriate for any 95th percentile male driver. . . Each passenger car whose inside rearview mirror does not meet the field of view requirements of S5.1.1 shall have an outside mirror of unit magnification or a convex mirror installed on the passenger's side.").

[3] 49 C.F.R. § 571.111 S4.

[4] Federal Motor Vehicle Safety Standards; Rearview Mirror Systems, 48 Fed. Reg. 38,842, 38,843 (Aug. 26, 1983).

[5] *Id.* at 38,842-43.

[6] Federal Motor Vehicle Safety Standard No. 111, Rear Visibility, 84 Fed. Reg. 54,533, 54,536-37 (Oct. 10, 2019) (discussing a study sponsored by the German government).

The FoV requirements under FMVSS No. 111 clearly presuppose interaction between human vision and mirrors. NHTSA must identify all assumptions about mirror-specific properties when the FoV requirements were drafted and determine whether CMS address each assumption in comparable ways.

B. Safety Benefits are Unclear

Although benefits unique to CMS (e.g., night vision, zooming, highlighting) appear enticing, no research has shown such benefits would offset the loss of mirror-specific properties. On the contrary, existing research has revealed potentially disconcerting safety issues.

NHTSA's own multi-year research of CMS on heavy vehicles identified excessive glare from the CMS visual displays, which could affect the "ability to see details in the forward roadway" and "be uncomfortable at night."[7] NHTSA's own testing with Audi A4 passenger vehicles again identified excessive glare that could "negatively impact the driver's ability to see obstacles at night," even when using a "nighttime" display mode.[8] The same testing also identified difficulties in seeing objects that the CMS screen would horizontally compress, and in seeing objects in rainy conditions under which droplets on the lens would obscure their images.[9] We are especially concerned that drivers may be oblivious to vulnerable road users such as pedestrians, cyclists, and motorcyclists whose images are obscured on the CMS screen.

As NHTSA is aware, a study sponsored by the German government identified a familiarization period for drivers to get used to a CMS, and this period could affect safety.[10] NHTSA is also aware of other studies and anecdotal experience indicating the possibilities of motion sickness and distraction due to a CMS.[11]

C. Preemption of State Law on Mirrors

Every state has mirror requirements for passenger vehicles. A missing or damaged outside mirror is an indication for law enforcement of potentially dangerous operation of a vehicle. At a time when the number of injured or killed vulnerable road users such as pedestrians and cyclists continues to rise every year, ensuring the safe operation of a vehicle, including adequate rear visibility, has never been more critical to state and local authorities.

If CMS become FMVSS-compliant, state vehicle inspectors must be trained to verify satisfactory CMS operation. Further, whereas broken or missing rearview mirrors are readily apparent to law enforcement officers who can and do cite drivers for inoperable mirrors, a failed CMS would not be readily apparent. To provide comparable enforceability, CMS-equipped vehicles should include an incapacity indicator readily

[7] *Id.* at 54,536.
[8] *Id.* at 54,537.
[9] *Id.*
[10] *Id.* at 54,536.
[11] *Id.* at 54,537.

observable to external viewers such as law enforcement. Alternatively, a CMS-equipped vehicle with a failed CMS could disable the ignition or the start button to ensure that drivers not operate the vehicle without adequate rear visibility.

Prior to permitting CMS as an alternative compliance option, NHTSA must devise a plan by which it will coordinate with and educate all 50 states, such that their vehicle inspectors and law enforcement know how to ensure CMS compliance with FMVSS No. 111.

D. Other Concerns

Cameras can fail in more ways than can mirrors. Absent crashes or other physical damage, mirrors often last the lifetime of the vehicle, whereas cameras are prone to technical failures, despite industry stakeholders' expectation that a CMS would withstand 15 years of environmental exposure.[12] Broken mirrors are relatively easy to replace, whereas replacement of broken cameras is likely to be both costly and time-consuming. In such circumstances, consumers will have a stronger incentive to take their chances than to fix their broken CMS, putting both themselves and other road users at risk, particularly if law enforcement is inhibited from citing violators because they can not observe whether CMS are operational.

E. Responses to NHTSA Questions

(1) *Please provide research data concerning the safety impacts of replacing rearview mirrors with CMS. Please explain your view of the significance of those data. In addition, please explain your views on how CMS-equipped vehicles would impact light and heavy vehicle driver behavior and situational awareness while driving.*

The Center for Auto Safety is concerned that NHTSA is contemplating the promulgation of a rule that alters a safety standard for which NHTSA does not have sufficient data demonstrating the change would provide comparable safety when compared with the status quos. More specifically, based on previously released information the Center is concerned about the excessive glare, image distortion, distraction, and motion sickness on a CMS screen. We also believe the need for driver adaptation represents a safety risk.

(2) *Are the physical properties of mirrors necessary to meet the stated purpose of FMVSS No. 111 to provide a "clear and reasonably unobstructed view?"*

To meet the stated purpose of FMVSS No. 111 in reasonably foreseeable circumstances, the physical properties of mirrors are required. CMS cannot provide the same spatial or color resolution as a human eye

[12] *See* Audi of America; Receipt of Petition for Temporary Exemption From FMVSS No. 111, 84 Fed. Reg. 56,013, 56,016 (Oct. 18, 2019).

viewing a scene in a mirror. Whereas mirrors provide depth perception available to a driver with stereo vision and/or head mobility, CMS do not. Whereas mirrors modify the driver's field of view in response to head motion, CMS in their current form do not. Whereas CMS are subject to blooming, flares, and obscuration due to water droplets or dirt on their cameras that can obscure small objects, (such as a motorcycle lost in the headlights of a following truck or multiple refractions of lights by water droplets on a camera lens) mirrors are not. Furthermore, CMS are less reliable than mirrors, since CMS become completely inoperable in the event of a power fault or processing error, neither of which affects mirrors.

No objective data has established that the potential benefits of CMS features such as zooming, night vision, and image processing will offset the loss of beneficial mirror-specific properties. As one example, the potential benefits of IR camera fusion with visible light images that might enhance night vision have not been empirically demonstrated. Alerts from images processed by a CMS have been reported but their beneficial impact on safety has not been evaluated.[13]

(5) *We seek comment on whether NHTSA should permit CMS that use multiple cameras to provide multiple fields of view to the driver in the same image display area.*

There is little empirical evidence available to support evaluating the safety impacts of multiple fields of view, missing sections, or image latency. The little work that has been reported has shown the need for driver adaptation to video images and to the location of the video displays, as well as the potential for driver distraction and disequilibrium with attendant motion sickness.[14] Proposals for amending FMVSS No. 111 must include objective evidence of satisfactory and safe fields of view, fields of regard, video display formatting, and location to avoid distraction and motion sickness. The limited data available do not provide a compelling case of safety even in the limited, benign environments typical of the test environments. Additional tests are required in more diverse environments and more challenging driving situations (e.g., avoidance of a small object at night when backlighted by a bright object such as a truck headlight; driver response to a rapidly changing scene that would induce head or body motion in a typical driver to quickly modify the field of regard) to establish safety levels equivalent to FMVSS No. 111-compliant mirrors.

[13] *See* Audi of America; Receipt of Petition for Temporary Exemption From FMVSS No. 111, 84 Fed. Reg. 56,013 (Oct. 18, 2019).

[14] *See, e.g.*, Elizabeth N. Mazzae et al., *DOT HS 812 582, Examination of a Prototype Camera Monitor System For Light Vehicle Outside Mirror Replacement* 40 (2018) (glare too bright in dark conditions; image obscuration in rainy conditions; substantial blooming of headlights in night driving and dark conditions); J.S. Mohamed Ali & F. Fatin Bazilah, *Mirrorless Car: A Feasibility Study*, 663 APPLIED MECHANICS & MATERIALS 649 (2014) (distracting downward glances; motion sickness).

(6) *NHTSA considered whether there might be any opportunities to combine either the cameras or the displays for the CMS with the camera or display for backup camera system that is required by FMVSS No. 111. The agency tentatively concludes that there would not be any such opportunities. NHTSA believes it is unlikely that it would be technically possible to combine the two systems in such a way that they share either a camera or display monitor. NHTSA requests comments on this tentative conclusion.*

The requirements and specifications for a safe CMS have not yet been established. It is therefore premature to evaluate incompatibility between rearview cameras and CMS since requirements and specifications do not yet exist. However, a notable distinction between the two components is their respective reliability requirements. A rearview camera supplements driver assessment of a vehicle's surroundings during the brief period of reverse motion, and is only used for a short time. Rearview cameras therefore need not be designed for continuous operation, and if inoperable, its function can temporarily be replaced by the driver's direct vision or personal inspection of the area where the vehicle will be positioned. The CMS must operate continuously and cannot be supplanted by alternate visual means if inoperable. This fundamental difference must be considered in any CMS implementation.

(7) *We seek comment on the minimum quality of the image presented on a CMS electronic visual display to provide the same level of safety as traditional FMVSS No. 111-compliant mirrors, as well as how image quality could be objectively measured. To what extent do existing CMS regulations (e.g., ISO 16505/UNECE R46) provide objective and repeatable performance requirements and test procedures to evaluate image quality? To the extent that those regulations do not provide such requirements and procedures, what changes or additions would need to be made? What new procedures, if any, would be needed to evaluate image quality appropriately and what has been done to develop such procedures?*

The minimum quality of the image presented on a CMS electronic visual display would provide detection and resolution of vehicles and vulnerable road users in all environmental and operational conditions at least as well as human vision using mirrors in the same conditions. It would be unacceptable to trade potential gains in field of view or field of regard for diminished safety of other vehicles or vulnerable road users. The ability to detect and resolve objects depends on display spatial resolution, color resolution, lighting, contrast, and adjustment for ambient lighting as well as human factors of attention and driver response to images.
Potentials exist for welcome enhancement and highlighting of critical objects in CMS visual displays, but such potentials have yet to be demonstrated in production-ready vehicles. Instead, data available to date have shown degraded images when compared with mirrors due to lighting

conditions, camera limitations, and environmental degradation of cameras.[15] Specification of all minimum image criteria should be based on empirical evidence that driver responses to those images are at least as safe as human responses to mirrored images in all environmental and operational conditions. Additional data is needed.

The FMVSS is, after all, a means to an end which is safe vehicle operation. Safe vehicle operation is grounded in human driver responses to the information provided by rear view mirrors specified in FMVSS No. 111. When suggesting replacement of the standard, it is important to ensure that a replacement technology enables those same responses. A new procedure is needed to validate human responses enabled by, and implicit in, the capabilities provided by FMVSS No. 111-compliant mirrors, and to verify that drivers using a proposed CMS exhibit comparable responses.

(8) *We seek comment on what disruptive display aberrations (blooming, etc.) should be addressed if the agency were to develop a CMS performance standard. To what extent do existing CMS regulations (e.g., ISO 16505/UNECE R46) provide objective, and repeatable performance test procedures to evaluate display aberrations? What new procedures, if any, would be needed to evaluate display aberrations appropriately and what has been done to develop such procedures?*

NHTSA should address the fact that small and dim objects (e.g., a motorcycle or pedestrian close to a truck headlight) are more easily lost in the glare, flare, or blooming of a digital camera than are potentially lost by a human eye and brain. Cameras have severely limited capacity for resolving small and/or dim objects near bright objects due to flare and blooming, and cameras have much less capacity than the human eye for leveling the apparent illumination exposure of differing parts of the visual field.[16] Any modification of FMVSS No. 111 for CMS should address this shortfall in visual resolution of vulnerable objects in certain commonly encountered lighting conditions.

(11) *We seek comment on how a driver should be alerted that a CMS is not operating correctly, such as during a malfunction or a software update.*

FMVSS compliance is required for safe vehicle operation. Therefore, if a vehicle were equipped with a CMS in lieu of mirrors and the CMS was

[15] *See* Elizabeth N. Mazzae et al., *DOT HS 812 582, Examination of a Prototype Camera Monitor System For Light Vehicle Outside Mirror Replacement* 40 (2018).

[16] Advances in dynamic metering are beginning to address this gap. *See DSLR Camera Basics*, NIKON, https://imaging.nikon.com/lineup/dslr/basics/18/01.htm (last visited Dec. 5, 2019) ("The camera does not simply measure the overall brightness of the frame, but measures brightness separately in multiple areas of the frame. The metering mode determines which areas of the frame are used by the camera to measure subject brightness and how the camera sets exposure.").

rendered inoperable for any reason, the vehicle cannot be operated safely and should be rendered inoperable by the control system. If the CMS became inoperable during operations, the vehicle should provide operator warning of the inoperability of the CMS and a means for notification of law enforcement. Once the trip is completed, NHTSA should contemplate requiring the vehicle to be disabled until the CMS or alternative FMVSS No. 111-compliant capability is restored. If CMS were inoperable before operations, the vehicle should remain immobilized. Driver notification should identify the CMS failure, but notification should not be considered a replacement for immobilization.

State safety inspections typically verify rearview mirror status. If CMS become FMVSS-compliant, individual states must be notified, and their inspectors must be provided the procedures for verifying satisfactory CMS operation. Further, inoperable rearview mirrors are readily apparent to law enforcement officers who can and do cite drivers for broken or otherwise inoperable mirrors. Unlike a broken mirror, a failed CMS would not be readily apparent to law enforcement. To provide comparable operational safety enforceability, CMS-equipped vehicles must include a readily observable incapacity indicator to external viewers such as law enforcement. In the absence of such external indicators, in the interest of safety, a CMS-equipped vehicle should be rendered inoperable at the conclusion of a trip if the CMS is not functioning for any reason (including obscuration due to environmental conditions as well as hardware/software faults).

(15) *We seek comment on the anticipated reliability of CMS as compared to outside rearview mirrors, including any reliability data that may be available for production or prototype CMS.*

We believe CMS are inherently less reliable than mirrors, since CMS become completely inoperable in the event of a power fault or processing error, neither of which affects mirrors.

(19) *We seek comment on whether NHTSA consider requiring that a CMS be capable of serving this function by being operational in some capacity either at all times or for a specified period of time after opening the driver's car door. What new performance criteria would need to be developed for this purpose and what has been done to develop those criteria?*

Many provisions in FMVSS, including No. 111, were developed with implicit human driver responses and capabilities in mind. FMVSS No. 111 established fields of view limits with the implicit understanding that human drivers with their adaptability would use the mirrors in many ways. Before modification of such FMVSS to accommodate additional motor vehicle rear vision mechanization, NHTSA should elucidate and make explicit the currently implicit driver actions and capabilities assumed and

enabled by mirrors compliant with the applicable FMVSS. Examples of such implied uses are use of rear view mirrors by drivers to determine whether it is safe to open a vehicle door after the vehicle has been shut down, parents monitoring behavior of children in rear seats, parents verifying seat belt use by rear seat occupants, drivers and passengers checking the environs for safe egress before opening a door, drivers moving head or body to quickly expand the field of regard, depth perception, etc. Before amending FMVSS to accommodate CMS as acceptable substitutes for rear view mirrors, NHTSA should determine what is required to enable these and other safety-related implied uses of rear view mirrors, and establish CMS requirements to replace those unstated, implicit but important alternate uses of rear view mirrors for operator and passenger safety.

(20) *Are there any other safety concerns that are closely related to the performance of CMS that are not addressed in this notice? If so, what are they, and what is the degree of their importance?*

NHTSA should consider the time-consuming nature of replacing a CMS as well as the cost thereof. Consumers may have an incentive to not replace a broken CMS if the replacement time is more than a minor inconvenience.

NHTSA should also consider how law enforcement could ensure CMS remain operational.

(21) We seek comment on the potential short-term and long-term economic impacts of CMS. In particular, we seek comment on the level of consumer interest in vehicles equipped with CMS. We also seek comment on the extent of reduced drag associated with the installation of CMS and on the resulting amount of improved fuel economy. Finally, we seek comment on the magnitude of the cost differential between equipping a vehicle with CMS and equipping a vehicle with rearview mirrors, and on the extent to which improved fuel economy would offset increased equipment costs associated with CMS.

The Center believes improving fuel economy is a laudable goal and one that should be encouraged through the use of new technology – much like auto safety. In this instance however, the agency has put forth an ANPRM contemplating introducing non-compliant, unproven technology without having verifiable data to demonstrate an actual increase in fuel economy, whether there is a detriment or improvement in safety, or evidence of a consumer interest in these changes.

F. Conclusion

The Center has consistently advocated incorporating available safety technology into motor vehicle safety standards wherever possible. We are always pleased to see

manufacturers looking for innovative ways to improve the safety of drivers, passengers, and other road users who interact with motor vehicles. With close to 40,000 deaths associated with motor vehicles annually, on and off public roads, technology that can assist with providing greater visibility of dangers is a public good. Moreover, technology which improves fuel economy should be encouraged where possible.

Real world experience has demonstrated that cameras, and their resultant monitors, can play a role in increasing visibility for users of motor vehicles, as they have with backup cameras. Backup-cameras, (mandated over industry objection finally became required a decade after they were passed into law) continue to reduce the horrors of back-up deaths and injuries every year. This ANPRM may serve as a good mechanism for gathering the necessary data to determine whether CMS can provide comparable, or increased, safety in the absence of mirrors, or whether it would be better to combine the use of mirrors and CMS.

Regardless of what data this ANPRM gathers, however, it should go without saying that a high bar must be set for any request to replace proven safety equipment with nascent technology. An even higher bar should exist for when NHTSA chooses to undertake non-mandated rulemakings for which there is no clear and obvious safety benefit, particularly when dozens of safety rules mandated by Congress sit gathering dust as they remain unwritten. NHTSA continues to prioritize rulemakings to align the FMVSS with automaker "cool-tech" that has little to no demonstrable safety benefits, over mandates passed by Congress that will save lives.

Unfortunately, at this time, there is simply insufficient evidence to justify replacing mirrors—which work in almost all cases—with cameras that do not necessarily provide comparable safety. The Center recommends that NHTSA not amend FMVSS No. 111 until research and data establish with reasonable certainty that CMS provide at least the same level of safety as do conventional mirrors.

Sincerely,

Jason Levine
Executive Director
Center for Auto Safety